U.S. Doc.
U.S. Mines Bu. of

Technical Paper 306

DEPARTMENT OF THE INTERIOR

ALBERT B. FALL, SECRETARY

BUREAU OF MINES

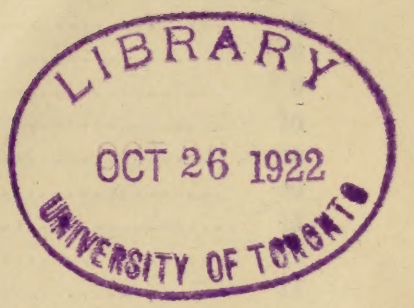
H. FOSTER BAIN, DIRECTOR

OPERATION AND MAINTENANCE OF ELECTRICAL EQUIPMENT APPROVED FOR PERMISSIBILITY BY THE BUREAU OF MINES

TN
23
.163
no. 306
NGINEERING
NGIN STORAGE

BY

L. C. ILSLEY



WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted, copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines.* His is an entirely separate office, and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The price of this publication is 5 cents.

II

First edition, June, 1922.

CONTENTS.

	Page.
Introduction	1
Rules relating to general safety	2
1. Maintaining the integrity of the approval	2
2. Practice of frequent and intelligent inspection	2
3. Attention to cleanliness	3
4. Proper assembly of equipment	3
5. Wiring of permissible apparatus	4
Capacity of the wires	4
Flexibility of the wire	4
Insulation of the conductor	5
Condition of the ends of the conductors	5
Support of the wiring	5
Trailing cables	5
Rigid-conduit wiring	6
Flexible-conduit wiring	6
Mechanical support of conduit	6
Securing the ends of flexible conduit	6
Fuse protection of the circuit	6
Inspecting circuits for proper fuses	7
Voltage of the circuit	7
6. Openings into permissible compartments	7
Openings around wires	7
Flange openings	7
Ventilating openings	8
Rules relating to specific schedules	8
Electric motors approved under Schedule 2–B	8
Inspection of coal-cutting machines	9
Inspection of electric drills	10
Inspection of loading machines	10
Electric miners' lamps approved under Schedule 6–A	10
Operation and maintenance of lamp batteries	11
Battery casing or inclosure	11
Locking the battery inclosure	11
Battery electrolyte	12
Adjustment of electrolyte for evaporation	12
Adjustment of electrolyte for leakage or spilling	12
Spilling of electrolyte	13
Periodic renewal of electrolyte	13
Keeping the battery clean	13
Instructions for charging batteries	13
Caution in regard to discharging lead cells	14
Mine-lamp battery troubles	14
Maintenance of the bulb and reflector	15
Maintenance of the lamp cords	15

Rules relating to specific schedules—Continued.
Electric miners' lamps approved under Schedule 6–A—Continued. Page.
Tampering with locks or seals ... 15
Assembly of lamps ... 16
Checking system ... 16
Single-shot electric blasting unit approved under Schedule 12 ... 17
Units of battery type ... 17
Units of the magneto type ... 17
Storage-battery locomotives approved under Schedule 15 ... 17
Routine inspection ... 18
Inspection of battery box ... 18
Inspection of motor with flanged cover over commutator ... 19
Inspection of controller ... 19
Inspection of rheostat with flange cover ... 19
Inspection of headlight ... 20
Inspection of the wiring between compartments ... 20
Miscellaneous inspection ... 20
Permissible equipment now available ... 20
Publications on electrical equipment for mines ... 22

ILLUSTRATIONS.

FIGURE 1. Types of flange joints used in construction of permissible equipment. 8
2. Explosion-proof interlocking switch ... 9

OPERATION AND MAINTENANCE OF ELECTRICAL EQUIPMENT APPROVED FOR PERMISSIBILITY BY THE BUREAU OF MINES.

By L. C. Ilsley.

INTRODUCTION.

Briefly, a permissible schedule of the Bureau of Mines establishes certain minimum standards for safety; it gives details of test methods adopted to determine whether these standards have been met, and a list of charges for such tests.

Any manufacturer has the privilege of submitting his product for test in accordance with the conditions outlined in the schedules. His action is wholly voluntary, for the Federal Government has no jurisdiction as to what equipment shall be used in mines, this authority being left to the various States. When the product of a manufacturer has met the schedule requirements, he is permitted to advertise this fact and to attach an approval plate with the bureau's seal to each machine he makes that is identical in every way with the equipment tested, inspected, and approved by the bureau.

This work of approval has grown by the addition of new schedules until at present a great many mines are using one or more classes of permissible equipment, and there is still a demand for other approved apparatus in the ever-widening field of electrically operated machinery.

The safety of electrical equipment of this type depends on four fundamentals, namely, (1) correct principles of design; (2) proper assembly of parts at the factory; (3) proper assembly and installation of equipment at the mine; (4) and proper operation and maintenance after installation. The first two factors are within the province of the manufacturer. The bureau either inspects and tests several models of one product, such as electric cap lamps, or one model, such as an electric motor. If this series of tests proves satisfactory, the manufacturer is given the privilege of making other appliances, and assembling them in the same way; the approval plate he attaches is his guaranty that the equipment is identical with the one tested and inspected by the bureau. The third and fourth factors concern those who use such permissible equipment, and it is to them that this paper is mainly addressed, in an effort

to show their responsibility in rendering electrical equipment safe for use in gaseous mines.

If machines never wore out; if parts never became loose or broken; if wiring never deteriorated; and if batteries never needed replacement, there would be no need of detailed instructions for maintenance of permissible equipment. But all persons connected with mining operations know that wear and tear start from the beginning of use, and that constant attention must be given to upkeep; therefore it will be necessary to discuss only the various points needing attention to prove to the average operator that he, also, has a task to perform in this fight for greater safety.

RULES RELATING TO GENERAL SAFETY.

A few rules that apply to nearly all makes and classes of permissible apparatus are discussed under six heads below.

1. MAINTAINING THE INTEGRITY OF THE APPROVAL.

An approval plate on a lamp, motor, or locomotive means that the manufacturer and the bureau believe that the apparatus, if maintained in the condition it left the factory, will prove safe from the hazards of gas in mines. The approval plate applies to the whole unit—not alone to the motor, but to all its controlling appliances—such as the controller, switch, or rheostat—and can not properly be used if any one of these auxiliary parts is changed and an unapproved part substituted, or if any change is made in any of the parts. In other words, the approval plate applies to a complete unit just as it was submitted, for permissibility, and any additions or subtractions or substitutions, render it nonpermissible.

If any one using permissible equipment wishes to make unauthorized changes in his apparatus, he should first, in justice to the manufacturer and the Bureau of Mines, remove the approval plate.

The bureau recognizes that constant change is necessary to keep up with the progress of electrical design, but every change must be taken up by the manufacturer, and then the approval should be extended to cover it after the bureau has carefully considered the effect on safety. By this procedure the bureau has on file all designs and modifications that have been approved. In event of disaster, the bureau's approval of the apparatus could not be expected to apply if the equipment causing the accident had been modified in any particular without the bureau's knowledge.

2. PRACTICE OF FREQUENT AND INTELLIGENT INSPECTION.

There is an old proverb that "an ounce of prevention is worth a pound of cure"; intelligent inspection is that ounce of prevention which prevents loss of equipment and time, and, for permissible apparatus,

may prevent disaster. An inspector should have knowledge of the equipment he is to examine, and should know what may render it unsafe. He should be willing to make a thorough and honest examination. He should make these inspections systematically, not look three times a week at the equipment which is readily accessible, and once in three years at the one at the foot of the slope. It is the latter that is most likely to need his attention, because the place is so far away "the inspector will never come way down here." When an inspector finds machinery that needs attention, he should see that defects are remedied.

The best results are obtained where an independent inspection department is maintained and the inspector is especially appointed for the work, reporting to some one having authority to see that needed repairs are made at once and reprimands are made where such are justified.

3. ATTENTION TO CLEANLINESS.

One of the chief requisites in the proper maintenance of permissible equipment is cleanliness. Current-carrying parts, such as commutator segments, that are properly spaced under conditions of cleanliness, will, if allowed to become dirty, permit leakage of current across the dirt path, thus causing arcing and short circuits. An electric current finds an easy path to ground through dirt. What was the cause of the last flat commutator? Dirt and grease which caused arcing of the brushes. What caused that cell to ground to the floor of the locomotive? Accumulation of dirt under the batteries. What caused that lamp to become dim? Dirty contacts. Dirt, grease, and coal dust, or a combination of these, allowed to accumulate, will render any equipment unsafe.

Point out a mine where the officials insist that electrical equipment shall be kept clean and neat, and there you will find a mine where the machinery is giving the best as well as the safest service. Systematic cleaning of permissible apparatus can not be recommended too strongly.

4. PROPER ASSEMBLY OF EQUIPMENT.

Permissible equipment, like all other apparatus, must occasionally be dismantled for renewals, repairs, and inspection. This work should be done by somebody with enough skill not to damage the parts either while taking them apart or reassembling them. If there were six bolts in the cover when it was taken off, six bolts must be put back. If a stud is broken off, drill it out and put in another. If the bolts are secured with nuts having lock washers or cotter pins, remember that these are part of the safety of the equipment and put them back. If some parts become lost, get new ones; do not send a crippled machine back into service. Do not make any temporary repairs of permissible equipment.

In reassembling use special care to avoid trouble from short circuits or grounds of electrical parts. If the insulation is bad on the lead wire, either repair it or change the wire. The very best practice, conscientiously carried out, should be the rule for all safety-first equipment.

5. WIRING OF PERMISSIBLE APPARATUS.

The following points should be considered when inspecting and repairing permissible apparatus:

(1) That the size (capacity) of the wires is sufficient for the maximum work performed; (2) that the flexibility of the conductors is suitable for that particular service; (3) that the insulation of the conductors offers ample protection for the prevailing conditions; (4) that the terminal ends of the wires have been properly soldered or clamped; (5) that the wiring has ample mechanical supports; (6) that the trailing cables are suitable and are adequately protected from injury; (7) that all ends of rigid conduit have been reamed and the conduit properly screwed together before the wire is installed, that insulation is not injured in placing the wire in the conduit, and that splices are not permitted except at proper outlets; (8) that all wiring in flexible conduit is installed with like precaution, with special attention paid to the maintenance of interlocked armor; (9) that all conduit is securely supported; (10) that the ends of flexible conduit are adequately held in place; (11) that all wiring is suitably fused; and (12) that the correct size of fuse is maintained. Each of these points will now be discussed under its own head.

CAPACITY OF THE WIRES.

For mining work, most manufacturers furnish machines with wiring of ample capacity, because they generally recognize that operating conditions are exceptionally severe and that overloading of most classes of equipment often happens because of poor voltage regulation and the common habit of adding all the load a motor will carry, regardless of whether the motor was ordered for this amount of work. The chief danger is then in replacement of wiring, especially trailing cables on portable machines, or rewiring where the wire has been damaged or has deteriorated from use. The safest plan in ordering new wire is to order it through the company supplying the equipment, sending a short sample of the original wire as an additional precaution.

FLEXIBILITY OF THE WIRE.

The degree of flexibility best suited for the service for any particular work is usually determined by practical results from actual service; therefore, when renewing wire, similar flexibility to the

original should be specified. This rule should be strictly adhered to, especially with trailing cables on portable equipment, such as coal-cutting machines.

INSULATION OF THE CONDUCTOR.

In renewing the wiring on permissible equipment, it is not only necessary to get wire of the same size and flexibility, but to take care to use wire having the same amount of insulation. The safety of the entire equipment depends on carefully designed insulation.

CONDITION OF THE ENDS OF CONDUCTORS.

More breakdowns are caused through troubles developing at the ends of conductors than at any other point in the circuit. Where two wires of opposite polarity are close together, a loose strand from one wire may touch the other conductor and cause a short circuit, unless special attention is given to see that no loose ends are left when soldering or clamping the ends of the conductors.

Poor workmanship in soldering, in removing too much or too little insulation, often causes trouble later on. Enough insulation should be removed to permit the wire to extend well into the terminal, but not to leave exposed wire outside of the terminal. Little details like these, which are so easily overlooked, may render a permissible machine entirely unsafe. Where the wire is held mechanically at the ends, care should be taken to see that all nuts, washers, and lock nuts are in place and are tightened securely. A loose wire is a hazard that never should be permitted in permissible apparatus.

SUPPORT OF THE WIRING.

Wiring should be well supported by means of cleats and clamps so as to eliminate all strains from the terminal and prevent abrasion of the insulation. Long, unsupported spans should not be permitted. The wiring should be so laid out that it can be protected from mechanical injury.

TRAILING CABLES.

Probably the greatest single danger from permissible apparatus is the external wiring. Special attention should be given to wire and its insulation at points where it leaves the apparatus, and where clamps are used. Motors having trailing cables offer the greatest hazard of all, unless such cables receive careful inspection. There are several safeguards that can be provided in using trailing cables. The size of such cables should be ample for the capacity of the motor. The cable should be sufficiently flexible and should have the best insulation available. Great care should be taken in making splices, which should be few on permissible equipment. Old cables requiring

frequent repairs should not be allowed to remain on permissible motors; if used at all, they should be transferred to parts of the mine where they can offer no hazard.

RIGID CONDUIT WIRING.

In laying wires in rigid conduit, care must be taken that there are no rough edges at the ends of the conduit and that all joints in the conduit are well screwed together; also in pulling in the wires, see that the insulation is not injured. Wires run in conduit should not be spliced, except at outlet boxes designed for such purposes.

FLEXIBLE CONDUIT WIRING.

The same attention should be given in wiring with flexible conduit or for rigid conduit.

While inspecting installations already made, give careful attention to the condition of the flexible armor, especially at the ends, to see that they are secure; also along the conduit to see whether the interlocked armor has become unlocked at any point, leaving rough edges which may destroy the insulation of the conductors.

MECHANICAL SUPPORT OF CONDUIT.

All conduit, whether of the flexible or rigid type, should be installed so as to be free as practicable from mechanical injury, should be amply supported by clamps, and, if need be, further protected from mechanical injury by guards.

SECURING THE ENDS OF FLEXIBLE CONDUIT.

It is not easy to secure the ends of flexible conduit properly. The clamps on the market have not been designed for such service, and mining installations may require the use of a specially designed clamp.

FUSE PROTECTION OF THE CIRCUIT.

Each wire in a circuit should be protected by a fuse or circuit breaker. Wires of different size require fuses of different capacities. For example, suppose that the main wires are No. 2 A. W. G. wire and can be protected with a 90-ampere fuse, and that from these main wires there is run a lighting circuit of No. 14 A. W. G. wire. This circuit should be arranged with low-capacity (15-ampere) fuse at the point where it leaves the main wiring, which will properly protect this smaller circuit; a short circuit in the lighting circuit will blow the low-capacity fuse and no damage will be done. If the fuse were not placed at this point, a short circuit in the lighting circuit would continue until enough current flows to blow the main fuse, with the result that the insulation on the small wires used in the lighting circuit would be destroyed, and, perhaps, a bad fire started or other serious damage done.

INSPECTING CIRCUITS FOR PROPER FUSES.

No inspection should be considered complete that does not check the protection of the circuit. Have fuses been provided to protect all the wiring? Have fuses of the right capacity been used in these circuits? And are fuses of proper capacity being retained, or are wires, nails, and all kinds of substitutes being used? No permissible equipment can be considered safe unless attention is being given to the correct maintenance of fuses.

VOLTAGE OF THE CIRCUIT.

A motor, or other part of electrical equipment, is designed to do its work at a certain voltage, and should not be expected to do its work properly unless this voltage is maintained within reasonable limits. Low voltage means a heavy current in the winding, which overheats the wiring, tending to destroy the insulation. Too high a voltage is also dangerous, as the spacing between parts has not been arranged for higher pressure, and arcs are often caused which break down the insulation with resultant serious damage.

6. OPENINGS INTO PERMISSIBLE COMPARTMENTS.

OPENINGS AROUND WIRES.

Were it feasible to design a motor, controller, or other electrical equipment with a metal casing having no openings to be covered, the maximum degree of safety would be had, since, whatever might happen within the casing, no flames, sparks, or electric arcs would come in contact with the surrounding atmosphere. Such design is not feasible because means must be provided for getting current to and from the apparatus, for daily inspection of commutator and controller segments, for installing bearings, for lubrication, and for changing parts, such as armatures and field coils.

Whatever scheme is adopted for bringing wires into permissible compartments, flames from the interior of the apparatus must be prevented from passing to the exterior through openings surrounding the wire. This is accomplished in various ways, and in rewiring it is very important that the openings around the wires are closed by the same method as used in the original wiring.

FLANGE OPENINGS.

Nearly all motors and their accessories are provided with flange metal-to-metal joints. In permissible motors the Bureau of Mines requires at least a 1-inch path of contact across this joint. This path may be in a straight or irregular line, as shown by *a*, *b*, and *c* of figure 1.

These joints are held together by bolts or screws so spaced as to pull the flanges tightly together when all bolts are in place. In permissible equipment it is very important that all bolts be kept in place and kept tight. Whenever feasible, lock washers or similar means of preventing the nuts from working loose should be used. When, for any reason, flange joints are disassembled, care should be taken not to damage the surfaces where contact is made, as rough handling might prevent their being drawn together again in proper manner.

VENTILATING OPENINGS.

If motors or other apparatus are provided with ventilating openings of the gauze or plate type, special attention should be given to keep these openings as free as possible from any accumulation of dust.

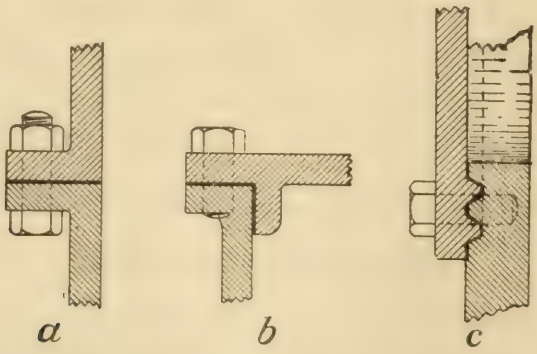


FIGURE 1.—Types of flange joints used in construction of permissible equipment.

RULES RELATING TO SPECIFIC SCHEDULES.

Under this head will be discussed practices that apply more particularly to a given class of apparatus. Many of the general rules already given should be followed also.

ELECTRIC MOTORS APPROVED UNDER SCHEDULE 2–B.[1]

Schedule 2–B covers the approval of electric motors; it gives the requirements for testing to determine the permissibility of electric motors such as are used on pumps, conveyer lines, drills, coal-loading and coal-cutting machines. All of the motor accessories, such as switches, controllers, fuses, and rheostats used, are considered a part of the motor, and are tested for permissibility with it.

A great deal of the equipment that will be approved under this schedule is to be used near the working faces of a mine, where the gas and dust hazards are greatest; therefore too much emphasis can not be placed on the importance of proper upkeep.

[1] Schedule 2–B is a revision of Schedule 2–A. It is entitled "Procedure for establishing a list of permissible electric motors; fees, character of tests, conditions under which tests and inspections will be made," and was approved August 16, 1921.

INSPECTION OF COAL-CUTTING MACHINES.

Coal-cutting machines are moved from place to place in the mine, are loaded and unloaded, and the cable is dragged along the floor and around corners; hence they are kept in permissible condition with more difficulty than stationary equipment. Consequently, safety requires that regular and thorough inspection of these machines be made at frequent intervals.

The outside wiring needs particular attention. First, inspect the wire from the motor to the reel, and then inspect the trailing cable. Look for defective insulation where the wire leaves the motor or reel and at points where it is clamped. See whether there are short bends. The wiring should be so taken off the machine that short bends in it are not necessary.

Does the cable need replacing? Have splices been made? Are these made in such a way and so insulated as to render the cable

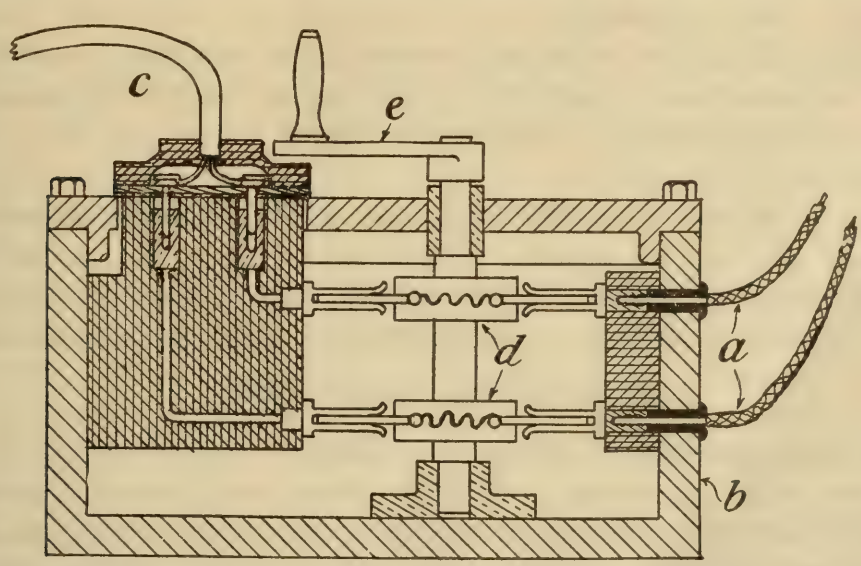


FIGURE 2.—Explosion-proof interlocking switch: *a*, incoming wires; *b*, explosion-proof compartment; *c*, trailing cable; *d*, fuses; *e*, switch handle.

as strong, both electrically and mechanically, as a new cable? What provision has been made for attaching the cable to the power supply? Are the ends of the conductor insulated so that the attendant can not receive a shock when making the connections? Is there a fuse at this point to protect the wiring should there be a short circuit in the trailing cable?

The maximum safety would be obtained if a fused switch were used at points where trailing cables are connected to the power supply. Figure 2 is a diagrammatic sketch showing the possible arrangement of the parts of such a switch. The incoming wires *a* enter the explosion-proof compartment *b* through close-fitting bushings. The trailing cable *c* is protected by the fuses *d*, and is interlocked by the switch handle *e*, so that it can not be inserted when the switch is closed nor removed until the switch is open.

Having made sure that the wiring external to the equipment is in a safe condition, the next step in inspection should be to determine whether all the permissible compartments are in proper condition; that is, that the bolts are all in place with lock nuts, cotter pins, etc.; that the covers all fit tightly; that the insulation around the wires where they enter permissible compartments is in place and in good condition; and that any ventilating openings, if these are provided, are free from accumulation of dust.

When necessary, the condition of the electrical parts within the casings, such as commutators, brushes, controller fingers, and segments, should be inspected; also the condition of all internal wiring.

Commutators and brushes should be kept in good repair. Even though the motors are tested for safety in case sparking takes place, this hazard should not be invited by allowing parts to become worn or out of adjustment, with the resultant excessive sparking and overheating of the commutator.

Bearings should be watched, as worn bearings may cause a burn out of the armature by permitting it to rub on the pole pieces and in extreme conditions may permit the flame to escape through the bearings.

Finally, do not knowingly let any part, either mechanical or electrical, get out of repair. Endeavor to keep the motor in its original condition with all bolts, screws, and fixtures in place; and then if trouble should occur, the fault will not be one of maintenance.

INSPECTION OF ELECTRIC DRILLS.

The same procedure should be followed in inspecting electric drills as was suggested for coal-cutting equipment. Although these drills are not as heavy or complicated as coal-cutting machines, they are moved from place to place with a trailing cable, and need the same kind of inspection.

INSPECTION OF LOADING MACHINES.

The inspection requirements for motors, controllers, and other electrical parts of loading machines follow the lines already outlined for coal-cutting machines, with this exception, that between permissible compartments there will undoubtedly be considerable wiring which will need special care to maintain it in a permissible condition.

ELECTRIC MINERS' LAMPS APPROVED UNDER SCHEDULE 6–A.

Schedule 6–A covers portable electric miners' lamps. The type that has been developed in the United States is chiefly the cap lamp. Schedule 6–A gives three requirements for electric lamps, namely, safety, practicability, and efficiency. All lamps are tested for liability of gas being ignited from the glowing filament in the bulb.

The battery is tested for strength, for amount of short-circuit current, for liability to spill electrolyte, and for its discharge characteristics over a 12-hour period. Lamp bulbs are tested for average and uniform life, and for uniformity of candlepower and current consumption. The lamp as a unit is tested for uniformity, amount, and angle of light distribution. The cords of cap lamps are tested for mechanical strength and general suitability.

OPERATION AND MAINTENANCE OF LAMP BATTERIES.

Storage batteries, called secondary batteries and accumulators, consist of two parts, the plates and a solution termed "the battery electrolyte." There are two kinds of storage batteries in general use, one having lead plates with an acid solution, the other having nickel-iron plates with an alkaline solution. The plates of lead batteries consist of a positive plate of lead oxide and a negative plate of pure lead, in a solution of dilute sulphuric acid. The plates of alkaline batteries consist of a positive plate of nickel hydroxide and a negative plate of iron oxide, usually in a solution of dilute caustic potash, but a similar solution of caustic soda can be used. Portable electric lamps have been developed with both lead and alkaline batteries, and the Bureau of Mines has approved makes of each type.

Lead batteries for portable electric mine-lamp service are made up in either two or four volt units; that is, they consist of a single lead cell or of two lead cells connected in series. Thus far the alkaline batteries for portable miners' lamps have been equipped with two cells connected in series giving a maximum of about three volts, which decreases during discharge to about two volts. It is improbable that single-cell alkaline batteries will ever be used for this service, owing to poor efficiency of bulbs at such low voltages.

BATTERY CASING OR INCLOSURE.

The Bureau of Mines makes dropping tests of the batteries in their inclosures to insure that with reasonable care the battery will be protected from injury. A lamp is not designed for duty as a car replacer, and anyone who uses the battery casing as a cushion between his body and a car when lifting cars back on a track will either crack or jam the battery casing and probably crack the rubber jar or so jam the casing as to short-circuit the battery plates.

LOCKING THE BATTERY INCLOSURE.

The battery casings of approved lamps are provided with locks. The bureau considers this requirement essential, as it affects the safety of the lamp. The purpose of the lock is three-fold, namely, to prevent malicious tampering with the battery; to prevent use of

the battery for shot firing; and to prevent the accidental ignition of explosive by inadvertent contact with the exposed battery terminals.

It is therefore necessary that locks be kept in good repair and that the lamp always be locked when delivered to the user. All keys should be kept in the care of the lamp-house attendant, and, more important yet, tampering with the battery by the user should be firmly discouraged by the mine officials.

BATTERY ELECTROLYTE.

It is extremely important that the electrolyte used in either lead or alkaline cells be free from all impurities. This requirement applies not only to the purchase of new electrolyte but to the keeping of the proper electrolyte, after purchase, in its original container until used and the addition of nothing but distilled water to the battery. Containers having electrolyte should be kept carefully labeled, as it would ruin either a lead or an alkaline battery to renew the battery solution with the wrong kind of electrolyte.

Lead batteries use a sulphuric acid electrolyte having a density between 1.17 and 1.20 when the battery is completely discharged; the density becomes between 1.25 and 1.28 when the battery is fully charged.

Alkaline batteries use either caustic soda or caustic potash as an electrolyte, the density of which does not change appreciably during the charge or discharge of the battery.

ADJUSTMENT OF ELECTROLYTE FOR EVAPORATION.

Both lead and alkaline batteries lose some of their electrolyte by evaporation; that is, some water escapes off as vapor, leaving the remaining electrolyte stronger—of a higher density—than it should be. All that is necessary to remedy this is to add as much distilled water as has evaporated and then to charge the battery, which thoroughly mixes the added water with the rest of the electrolyte, bringing the solution in the battery to a proper uniform density. Do not replace the evaporated water by adding electrolyte; such addition will increase the density of the solution and may injure the battery plates.

ADJUSTMENT OF ELECTROLYTE FOR LEAKAGE OR SPILLING.

If electrolyte has leaked or spilled from a cell, the only remedy is to add more electrolyte of the proper density. To do this is much more difficult than to add water to replace evaporation, and probably can not be done properly until the lamp man has had considerable experience. One method that can be adopted is to discharge the cell to its allowable discharge voltage, then pour off the electrolyte, and add a new solution of the proper density. When adjusting electrolyte in lead batteries, one should always remember that the density will increase as the cell is charged.

SPILLING OF ELECTROLYTE.

The Bureau of Mines tests the batteries of all approved lamps to determine whether the batteries spill electrolyte through the air vents. All approved lamps have passed these rigid tests, and if in actual service they do not give satisfaction, the cause is probably due to one or more of the following reasons: The cell is too full of electrolyte; the vent has become clogged; or some other defect has developed in the lamp. Whatever the cause, it should be found and the leak stopped, as the electrolyte, if it does not burn the user, will at least ruin his clothing.

PERIODIC RENEWAL OF ELECTROLYTE.

Renewing periodically the electrolyte of all batteries will probably increase the efficiency of any installation of lamps. Where the installation is large, the renewing should be done in conformity with the instructions of lamp or battery manufacturers, as such renewals always involve considerable expense.

KEEPING THE BATTERY CLEAN.

Attention should be given to the general cleanliness of batteries. Electrolyte spray and accumulations of dirt should be removed from the cells after charging. This attention not only adds much to the general appearance of an installation but tends to prolong the useful life of the lamps. Similar attention should be given to the charging racks and other accessories used in connection with charging.

INSTRUCTIONS FOR CHARGING BATTERIES.

To charge a battery, always connect the positive wire of the charging circuit to the positive side of the battery circuit. The charge on lead cells can be determined by taking frequent readings with either a hydrometer or a voltmeter. When checking the condition of the charge with a hydrometer, the charging should be continued until the reading does not increase; that is, if the reading on a cell was 1,240 at 9. m., 1,270 at 10 a. m., and was still 1,270 at 11 a. m., this would indicate that the cell was completely charged. When checking the charge with a voltmeter, care should be taken that the voltmeter has a low-reading scale and is reasonably accurate. The readings of a fully charged single lead cell during charging will range from 2.4 to 2.6 volts, depending upon the density of the electrolyte and the age of the battery. Batteries should not be charged for more than one hour after the voltage ceases to rise. Each battery has a proper charging rate which depends on the size and design of the plates. This rate will be given by the battery manufacturer and should not be exceeded. Unless lamps bulbs are used for resistance, it will generally be necessary to have an accurate ammeter to deter-

mine when the proper current is passing into the battery. Prolonged overcharging injuries the batteries; charging at too high a rate heats the plates and shortens their life.

The condition of charge of an alkaline cell can not be determined by a hydrometer, but can be ascertained by a voltmeter. A fully charged lamp battery (two alkaline cells in series) registers about 3.5 volts when fully charged. Alkaline batteries can be safely charged by the time method—that is, for a given number of hours at a certain current rate. In charging either lead or alkaline cells always keep the electrolyte at the proper height above the battery plate.

CAUTION IN REGARD TO DISCHARGING LEAD CELLS.

Lead cells should not be discharged below 1.75 volts—the measurement being taken while the load is on the battery. The working range of a lead cell is usually given as 2.2 to 1.8 volts; the working range of an alkaline battery (two cells in series) is approximately 3 to 2 volts. The voltage below 2 volts falls so rapidly that it serves no useful purpose. It does not damage an alkaline cell to discharge it completely, or if by mistake an alkaline cell has been charged backward, it can be discharged and charged in the right direction without being seriously damaged.

PROBABLE LIFE OF LAMP BATTERIES.

The Bureau of Mines does not make life tests of batteries used on electric lamps, but the performance of the batteries is studied during a short period while the lamp bulbs are being tested for life and uniformity. Also, field inspections are made by the bureau's electrical engineer, and reports are obtained from both users and lamp manufacturers. As a result of this general information, the bureau believes that lead cells will give 300 shifts of 12 hours each, and alkaline cells 600 such shifts, without plate renewals.

MINE-LAMP BATTERY TROUBLES.

The most common troubles experienced with batteries used with electric mine lamps are short-circuited cells, leaky cells, and loss of capacity.

Short circuits often are caused by rough handling, such as dropping the lamp, or jamming or denting the battery casing. Sometimes short circuits are caused by deterioration of the battery plates; sometimes small pieces of material fall to the bottom of the battery jar and accumulate in such quantities as to make contact between the positive and negative plates; or the plates bulge and press through the insulation separating the plates, making a short circuit at that point.

Short-circuited alkaline cells should be returned to the manufacturer's agent for repair. Short-circuited lead cells may be repaired if the lamp attendant has proper supplies, time, and skill.

If the electrolyte is not of the proper density, the battery will not work satisfactorily. Frequently it happens that too much water has been added from time to time, diluting the electrolyte far below its original density.

Leaky cells are caused by ineffective seals, by cracks in jars, and by opened seams. Whenever such leaks are detected the battery should be put out of service until repaired.

Some decrease of capacity is sure to take place in any storage battery, as the very thing that permits the battery to do its work slowly wears it out. Lamp attendants will learn to know the difference between this gradual loss and the sudden loss caused by weak electrolyte or a partial short circuit in the cell.

MAINTENANCE OF THE BULB AND REFLECTOR.

The bulb and reflector are the light-giving parts of the lamp. The bulb is designed to give a life of 200 to 300 hours, but some bulbs give a much longer life before actually burning out. Bulbs approved by the Bureau of Mines have not only been tested to determine their practicality and efficiency, but also have been tested for their safety in connection with the operation of the safety device in the headpiece; therefore, bulbs other than those approved should never be used, as this substitution may interfere with the action of the safety mechanism.

The reflector used with approved lamps is designed to distribute the light from the headpiece evenly and at such an angle that the average person has a completely lighted area in which to work. A more concentrated lens gives a smaller circle of light but causes a dark area within it, and is harmful to the user's eyes. Frequently a lamp attendant or miner changes reflectors, a practice that should be discouraged, as any change in the lamp makes it an unapproved lamp. Reflectors should be kept clean, but should not be treated with paint or special preparations by the lamp attendant. Keep the headpiece as tight as possible, in order to keep dust away from the reflector. When reflectors become inefficient they should be replaced by new ones.

MAINTENANCE OF LAMP CORDS.

Carrying lamps by the cords should be prohibited. Defective cords should be renewed when badly frayed. Cords should never be spliced, as the saving is doubtful and the practice not in keeping with the standards of permissible equipment.

TAMPERING WITH LOCKS OR SEALS.

A lamp is not an approved lamp unless it is locked. The user should not have a key or other means of opening a lamp casing. All tampering with locks or seals should be punished. No lamp whose lock is out of repair should be given out; the lock should be repaired before the lamp is used.

ASSEMBLY OF LAMPS.

In assembling lamp parts care should be taken to get each part in its proper place. Special attention should be taken where there is a liability of short circuit or ground.

CHECKING SYSTEM.

The following system for checking lamps and identifying men using electric lamps has been suggested in a circular issued by the Koehler Manufacturing Co., and used for installations of Wheat electric cap lamps:

1. This is a system to eliminate writing by the lamp man, and to make it easy for him to keep an up-to-date account of his lamps.

2. It makes it easy and speedy for the lamp man to get a record of lamps given to new miners going to work for the first time without holding up the line.

3. Blank cards are kept in the mine office, and when a new miner goes to work the clerk in the office takes the miner's name and gives him a mine number in the pay book. The clerk then writes the man's name and mine number on one of the cards, gives it to him, and tells him to hand it to the lamp man for a lamp.

4. When this card is handed in at the lamp house it is only necessary for the lamp man to give the miner a lamp not already assigned and place the card in the compartment from which he took the lamp and leave it there until after all the lamps have been given out for the shift. He may then mark the number of the lamp given to the miner on the card and put it in its proper place in the card-index box. He will then have a lamp number and compartment number on the card, as they are both the same. Each lamp is always placed in the compartment bearing the same number.

5. When the lamp is returned the miner receives the regular brass check which he will use thereafter. When the miner quits his job his card is destroyed, and the lamp is ready to be given out to another man when a new card, that has been made out at the mine office, is handed to the lamp man.

6. In this way the card index is kept up to date at all times and will be found very useful in making out monthly lamp reports, sheets for which are furnished with this system. These sheets are laid out in such a way as to make it very easy for the lamp man to make his daily report of lamps in use. This is done by merely placing a check mark in the space provided for each date on the line opposite a man's name. It is only necessary for a clerk to copy the names and mine numbers from the card index onto the sheet once a month. By simply signing his name and turning in the sheet the lamp man's monthly report is finished.

7. When properly kept this system makes the most satisfactory way of successfully handling lamps.

8. In case of an explosion or other accident, the lamp, being attached to the men's belts, constitutes a reliable identification check, as a miner will never abandon his lamp. The card in the lamp house bearing his lamp number will give all necessary information. This is a vital reason for keeping this combined lamp and body check system up to date at all times.

9. In case the miner does not return at the end of a shift, his name and working place can be given to the foreman in charge of the following shift so that he may investigate. This will eliminate the possibility of a miner being caught by falling roof or other conditions and not being found for many hours, and possibly prevent loss of life.

10. By proper use of this system a constant check is maintained on both lamps and men, and desired information is always instantly available.

SINGLE-SHOT ELECTRIC BLASTING UNITS APPROVED UNDER SCHEDULE 12.

Schedule 12 covers approved single-shot blasting devices, either of the battery or the magneto type. One equipment of each type has been approved.

The Bureau of Mines believes that the introduction of approved single-shot firing equipment, especially in those mines where shots are at present fired by means of a fuse, will greatly increase safety, and for that reason is anxious that this class of permissible equipment shall be handled correctly and well maintained, in order that its popularity and general use shall increase.

One of the factors affecting the safety of these devices is that the firing of only one shot at a time is recommended. When a blasting unit is used in this way there is practically no danger of not detecting a misfire.

UNITS OF BATTERY TYPE.

In order to have devices of the battery type operate properly, the following rules should be observed:

Use a freshly charged battery.

Use good grades of rubber-insulated wire for making connection to circuit.

Do not have splices or bare spots in your wire.

Have the connecting plug working free in the receptacle.

Avoid a short circuit in the battery.

Do not connect your battery until ready to fire.

Do not fire until all persons in the vicinity have been warned and have gone to a safe shelter.

Use only approved devices.

UNITS OF THE MAGNETO TYPE.

The rules for satisfactory operation of devices of the magneto type are as follows:

Keep the magneto in good condition.

Do not break the seals of parts that are sealed.

Use good quality rubber-insulated wire for making circuit connections.

Do not use spliced wire or permit bare spots.

Do not connect magneto until ready to fire.

Do not fire until all persons are out of danger.

Do not use unapproved devices.

STORAGE-BATTERY LOCOMOTIVES APPROVED UNDER SCHEDULE 15.

Under Schedule 15 are approved storage-battery locomotives for use in gaseous mines. The approval includes all of the electrical parts of the locomotive, such as the motor, controller, resistance, headlight, ampere-hour meter, battery, switches, fuses, and all wiring.

The electrical parts of a storage-battery locomotive are so complicated that maintenance in a permissible condition requires earnest effort, and real safety can be obtained only through the complete sympathy and cooperation of the user of the locomotive.

Locomotives approved by the Bureau of Mines should not be confused with so-called "explosion-proof" locomotives remodeled at the mine. The Federal Government's approval covers only such equipment as has the name plate with the bureau's seal.

Permissible storage-battery locomotives differ in a number of ways from most locomotives previously used. Parts such as the motor, controller, fuses, and switches, which are at any time liable to spark, flash, or arc, are inclosed in specially designed compartments. The flange joints of these compartment are designed to have at least 1 inch metal-to-metal surface, and are securely bolted together. The bolt holes are so planned that if by an oversight a bolt should be omitted there would be no hole through the casing into the interior of the compartment. All leads entering such compartments are carefully bushed, packed, or otherwise safeguarded, so that there shall be no opening around the lead into the compartment. Bearings are investigated to determine whether there is a liability of flames passing through the bearing housing. Besides this careful inspection for possible openings, tests are made in mixtures of gas and air. Actual explosions are made within all permissible compartments while they are surrounded by the same explosive mixture, in order to make sure that flames can not issue from the compartments.

The battery jars and the headlights are given a severe bumping test to prove their suitability for hard service. The battery compartments are investigated to determine whether ample ventilation has been provided for the gassing of the batteries during discharge.

The wiring between compartments is inspected to see that it is well supported, that ample clearance has been provided from moving parts, and that the ends of the conduit are secure.

ROUTINE INSPECTION.

The following routine is suggested for the inspection of a permissible storage-battery locomotive. This inspection should be made not in a gaseous section of a mine but on the fresh-air intake, or, when feasible, outside the mine. The battery box should be examined first and the following points should be noted:

INSPECTION OF BATTERY BOX.

1. Is the cover of the battery box locked?
2. In whose possession is the key?
3. Are all of the cells in service?

4. Is there sufficient electrolyte in the cells?
5. Are the jumpers or connectors between cells in good condition and tight?
6. Is all the other wiring in the battery box in good condition and properly cleated?
7. Are the cell tops free from dirt and electrolyte?
8. Is there dirt between the battery trays?
9. Is there dirt underneath the battery trays?
10. Are all tray insulators in place and in good condition?
11. Is there any leakage of current from the battery to the frame of the locomotive?

INSPECTION OF MOTOR WITH FLANGED COVER OVER COMMUTATOR.

1. Is the cover in place and held down by a full set of bolts with lock washers?
2. Are the flange surfaces clean and clear from burrs, so that the cover can be closed tightly?
3. Is the commutator in good condition?
4. Are the brushes in good condition?
5. Do the bearings need renewal?
6. Are the bearings receiving proper lubrication?
7. Is there excessive lubrication, so that the wiring is becoming saturated with oil?
8. Are the wires properly bushed where they enter the motor casing?
9. Are all bolts in place and properly secured with nuts, lock washers, etc.?

INSPECTION OF CONTROLLER.

1. Is the controller locked?
2. In whose possession is the key?
3. Are all the fingers making good contact with the segments?
4. Do any of the fingers or segments need changing?
5. Are the contact surfaces greased to prevent excessive wear?
6. Are all wires tight where they enter terminals?
7. Is the blow-out coil in working order?
8. Is the arc-deflector board in good condition?
9. Are the openings around all wires leaving the casing closed and in the same condition as when first received?
10. Are all bolts in place and all nuts secure?

INSPECTION OF RHEOSTAT WITH FLANGE COVER.

1. Is the cover in place with full number of bolts, securely fastened?
2. Are flange surfaces in good condition?
3. Are there any loose or broken resistance grids?

4. Are there any loose connections?
5. Is the insulation on wiring baked?
6. Are the wires in good condition where they leave the compartment?
7. Are all bolts in place and securely locked?

INSPECTION OF HEADLIGHT.

1. Is the headlight securely bolted down?
2. Is the guard over the glass whole?
3. Is the glass whole?
4. Is the headlight compartment sealed?
5. Is the bulb in place?
6. Is the wiring in good condition?
7. Are all bolts in place and nuts secure?

INSPECTION OF THE WIRING BETWEEN COMPARTMENTS.

1. Is all the conduit in good condition?
2. Are all the clamps supporting the conduit in place?
3. Do any of the moving parts rub the conduit at any point?
4. Note especially the condition of the flexible conduit where the ends are held. Are these all in good condition?

MISCELLANEOUS INSPECTION.

1. Are the fuses in place?
2. Are the proper fuses being used?
3. Are the charging plug terminals in good condition?
4. Is the ampere-hour meter in good condition?
5. Are there any repairs that need immediate attention with regard to safety?
6. Have the repairs recommended at the last inspection been made?

PERMISSIBLE EQUIPMENT NOW AVAILABLE.

The Bureau of Mines permissible list of electric equipment is as follows:

COAL-CUTTING MACHINES.

Approval No.	Apparatus.
100	Sullivan CE–7 d. c. machine with 250-volt motor.
100–A	Sullivan CE–7 d. c. machine with 500-volt motor.
101	Goodman 23–C d. c. machine with 210-volt motor.
101–A	Goodman 23–E d. c. machine with 500-volt motor.
102	Jeffrey 28–A d. c. machine with 250-volt motor.
102–A	Jeffrey 28–A d. c. machine with 500-volt motor.
103	Jeffrey 35–B d. c. machine with 250-volt motor.
103–A	Jeffrey 35–B d. c. machine with 500-volt motor.
104	Sullivan CE–7 a. c. machine with 250-volt motor.
104–A	Sullivan CE–7 a. c. machine with 440-volt motor.

Approval No.	Apparatus.
105	Goodman 40–C d. c. machine with 500-volt motor.
105–A	Goodman 40–C d. c. machine with 500-volt motor.
106	Goodman 40–C (universal type) d. c. machine with 210-volt motor.
106–A	Goodman 40–C (universal type) d. c. machine with 500-volt motor.
107	Goodman 23–E d. c. machine with 210-volt motor.
107–A	Goodman 23–E d. c. machine with 500-volt motor.
108	Goodman 23–E (universal type) d. c. machine with 210-volt motor.
108–A	Goodman 23–E (universal type) d. c. machine with 500-volt motor.

PORTABLE ELECTRIC MINERS' LAMPS.

10	Edison electric cap lamp.
12	Concordia electric hand lamp.
14	Wico electric cap lamp.
15	Concordia electric cap lamp.
17	Wheat electric cap lamp.

SINGLE-SHOT BLASTING UNITS.

1,200	Mine Safety Appliances Co.'s single-shot blasting unit (battery type).
1,201	Davis single-shot blasting unit (magneto type).

STORAGE-BATTERY LOCOMOTIVES.

1,500	Whitcomb storage-battery locomotive.
1,501	Jeffrey storage-battery locomotive.

PUBLICATIONS ON ELECTRICAL EQUIPMENT FOR MINES.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 38 pp., 6 pls., 1 fig.

BULLETIN 78. Approved coal-cutting equipment, by L. C. Ilsley and E. J. Gleim. 1920. 53 pp., 18 pls., 3 figs.

BULLETIN 131. Approved electric lamps for miners, by H. H. Clark and L. C. Ilsley. 1917. 59 pp., 17 pls., 7 figs.

TECHNICAL PAPER 44. Safety electric switches for mines, by H. H. Clark. 1913. 8 pp.

TECHNICAL PAPER 75. Permissible electric lamps for miners, by H. H. Clark. 1914. 21 pp., 3 figs.

TECHNICAL PAPER 79. Electric lights for oil and gas wells, by H. H. Clark. 1914. 8 pp.

TECHNICAL PAPER 138. Suggested safety rules for installing and using electrical equipment in bituminous coal mines, by H. H. Clark and C. M. Means. 1916. 36 pp.

TECHNICAL PAPER 264. Preliminary investigations of storage-battery locomotives, specifications, laboratory tests, permissible schedule, by L. C. Ilsley and H. B. Brunot. 1921. 35 pp., 2 pls., 4 figs.

TECHNICAL PAPER 271. State mining laws on the use of electricity in and about coal mines, by L. C. Ilsley. 1920. 53 pp., 1 fig.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

TECHNICAL PAPER 23. Ignition of mine gas by miniature electric lamps with tungsten filaments, by H. H. Clark. 1912. 5 pp. 5 cents.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp. 5 cents.

TECHNICAL PAPER 47. Portable electric mine lamps, by H. H. Clark. 1913. 8 pp. 5 cents.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs. 5 cents.

TECHNICAL PAPER 101. Permissible explosion-proof electric motors for mines; conditions and requirements for test and approval, by H. H. Clark. 1915. 14 pp., 2 pls. 1 fig. 5 cents.

○